Concurrent Real Time Engineering Via the "Fredrik" Work Environment: Helping Engineers Produce Their Products by Structuring Their Access to Relevant Information

Susan K. Volk
Jet Propulsion Laboratory
Susan.K.Volk@jpl.nasa.gov

Rebecca Wheeler
Jet Propulsion Laboratory
Rebecca.L.Wheeler@jpl.nasa.gov

Belinda Wilkinson
Jet Propulsion Laboratory
Belinda.Wilkinson@jpl.nasa.gov

Michael Jones
Jet Propulsion Laboratory
Michael.K.Jones@jpl.nasa.gov

Susanne Birgel
Jet Propulsion Laboratory
Susanne.Birgel@jpl.nasa.gov

Abstract

This paper describes a real life case study for a web based prototype design environment to support the generation and documentation of mission concepts that will result in mission proposals to NASA. This design environment, nicknamed Fredrik, provides a structured process and access to tools and data sources required to produce design products during a real time concurrent engineering design session for a multidisciplinary team of system engineers and scientists in the Jet Propulsion Laboratory (JPL) Project Design Center (PDC).

This prototype produced immediate collaborative design process performance improvements, based primarily on the product and process definition insights gained by involving the end user proxy in defining how best to use the current team and facility capabilities within the Fredrik environment. In addition, the study products contain formatted information stored in a database for immediate use in multiple ways (i.e. presentations, sections of proposals) and for future design process re-use.

1. What is Fredrik?

Fredrik is the nickname for a web based environment that structures a design process and provides the user access to tools and data sources required to support the design process and its products. The key attributes of Fredrik are:

- An Information Technology (IT) system based upon the process user's inputs and their existing work environment;
- A web based architecture (platform independent and distributed access);
- Information focused on "how to do the work" - hypertext links to product development information and tools;
- A back-end database providing dynamic functionality and multiple routes (indices) to access information (i.e. product, role, process);
- An inheritance model
  - Fredrik "Senior": Contains generic work processes, key events, work elements, product descriptions and related information for a class of users (e.g. engineers),
  - Fredrik "Junior": Customized Fredrik Senior based on specific user's actual product production process and documentation needs;
- Information re-use - Population of Fredrik Senior is on-going as re-usable, applicable, project-developed information is produced by Fredrik "Juniors" and transferred to Fredrik Senior for re-use by similar users;
- Real time information publishing enabled via distributed uploading capabilities;
- Easy integration with project and document management tools.

The ultimate goal of Fredrik is to help users produce their products more efficiently. To achieve this goal Fredrik:

- Implements a well suited IT solution that improves a user's capability to produce one or more end products;
- Helps users produce their products by structuring their access to relevant information.

The ultimate objective is to have users happily using the solution that they helped implement. [1]

2. Background

Fredrik is a further evolution of a web based tool developed at JPL to support the capture, organization and dissemination of JPL proposal process information called Hypertext Approach to Documentation And Management (HATDAM). HATDAM had proven to be a useful tool for proposal managers, but lacked the capabilities required for a web based concurrent user information system.

Inherited from HATDAM is the process for designing an IT system and the team that developed it.

The process for development of an IT solution is iterative. It is dependent on continuous management support, frequent interaction with users, measurement of user satisfaction, continuous improvement of the solution based on user feedback, and continuous update of information.

An IT solution must start with the user requirements for their products, current work methods and desires to change them, institutional and programmatic constraints, and information management needs. An initial incremental IT solution is defined by focusing on a limited area of products or work methods that would benefit from the application of immediately available and affordable IT solutions. It is implemented and metrics are collected on the effectiveness of the solution. These metrics provide information to determine requirements for later incremental solutions. [2]

The HATDAM/Fredrik development team brought four years of proposal process experience and the skill set required to develop a collaborative IT system for JPL. Each person on the team has a different area of discipline:

- system architect,
- information system engineer,
- software system developer,
- database designer/developer,
- web design/user interface,
- system analysis.

Inherited from the existing concurrent engineering environment are the facilities and equipment of the Project Design Center (PDC) and the system level engineers (Team A) of the JPL mission design team, nicknamed Team X. (See Figure 1. for the PDC/Team A facility and equipment configuration.)

This Fredrik IT system development process, team and existing concurrent engineering environment are the key elements of the collaborative case study described in Section 4.
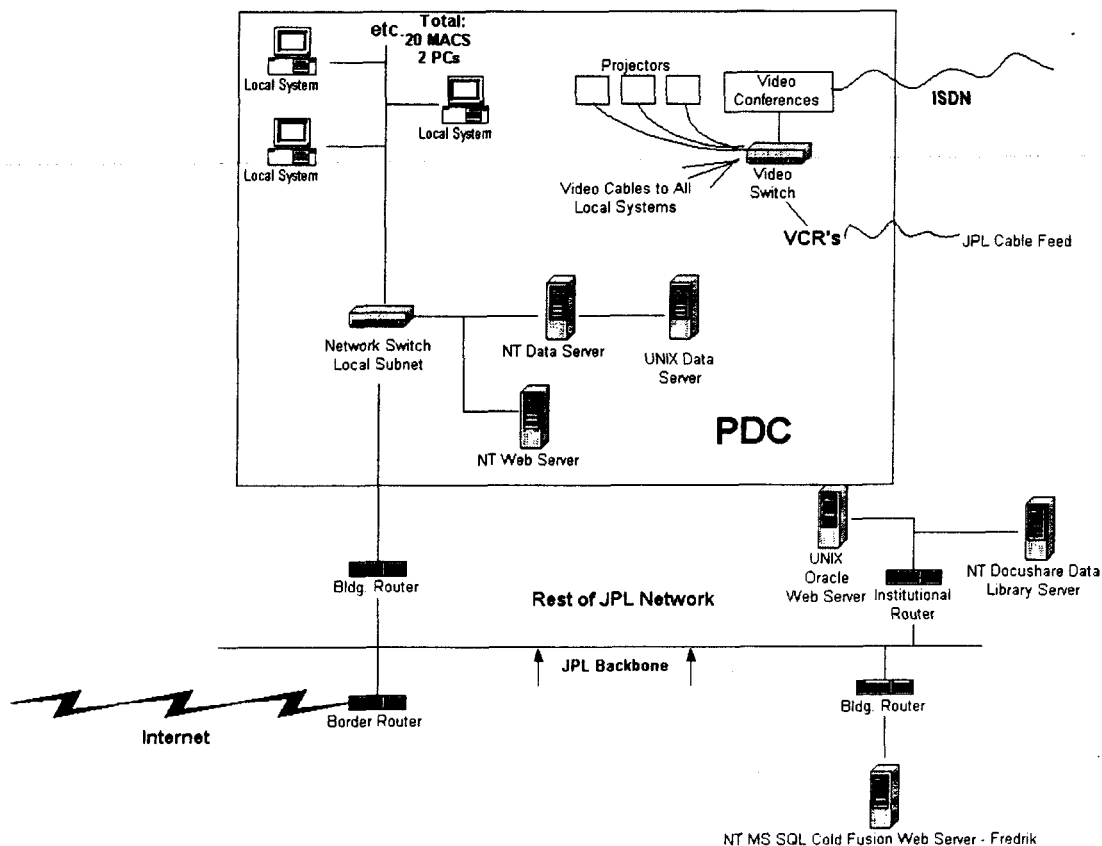

Figure 1. Facilities and equipment at JPL PDC: current configuration

3. Significance

The Fredrik work recognizes and draws upon emerging methodologies in the fields of knowledge management (KM), organizational learning, and cognitive system engineering. KM theory is advancing with new concepts grouped together under the banner of "second-generation knowledge management" (SGKM). These concepts merge ideas from organizational learning and include "demand-side knowledge management" which emphasizes accelerating the production of new knowledge rather than the codifying and sharing of existing knowledge. Demand-side KM initiatives focus on enhancing the conditions in which innovation and creativity naturally occurs. [3]

The field of cognitive system engineering includes methods for designing systems to help people carry out their daily tasks. These systems must be acceptable and useful immediately. The application of these methods to information systems requires the integration of modeling concepts from many different disciplines: engineering, psychology, and cognitive, management, information, and computer sciences. The Fredrik prototype applied these methods for the case study defined in the following section. [4]

4. Team A Fredrik: Real Time Mission Design Environment [5]

The Space and Earth Science Programs Directorate (SESPD) is the organization responsible for developing new science mission concepts at JPL. The SESPD sponsored a case study to develop a Fredrik prototype, designed specifically to support NASA Small Explorer Program (SMEX) mission proposals. This was a 6 month study (May-September, 1999).

The goal of the study was to test an improved process that would enable a multidisciplinary design team, nicknamed Team A, to produce more efficient and immediately usable mission design products for early phase proposal teams, and a work environment (Fredrik) to support the improved process and products. The following were the objectives of the Team A study:

- decrease the number of participants in the mission design sessions for early phase proposals by involving only the systems positions (Team A) of the current mission design team (nicknamed Team X) (50% reduction in team size);
- decrease the number of design sessions by 50%;
- streamline the product development process by:
  - simplifying and standardizing the type of products produced,
  - changing from a text document to a viewgraph format,

- developing templates as a starting point for the production of each of the design session user's products;
- involve an end user proxy, representing the SMEX proposal managers, in negotiations with Team A for changes to their product development process;
- implement and test a prototype Fredrik work environment to support Team A's working process;
- provide access to templates, examples, instructions, tools and references linked to production of each of ten products negotiated with the end user proxy;
- store and protect the proprietary products produced for immediate access by the design session user as well as later access or re-use by the mission design team.

4.1. Implementation Approach

The implementation approach for the Fredrik/Team A Task is illustrated in Figure 1 below. The philosophy behind the approach includes two major tenets:

- The Fredrik Team would only consider itself successful if the immediate users (Team A) were using Fredrik to produce real end products for real end users (proposal managers investigating potential mission concepts).
- Any Fredrik prototype must closely fit Team A work processes in order for Team A to readily accept, use, and critique the information structures and technologies featured in Fredrik.

Therefore, the implementation approach included early and continuing interaction with both Team A and the end users.

The following are descriptions of the Fredrik/Team A major implementation approach phases.

4.1.1. User Interaction and Analysis In order to define the needs of the end users, the Fredrik Team set up and moderated a series of discussions between a knowledgeable proxy for the end users and the members of Team A. In order to promote detailed discussions, the Fredrik Team generated examples of the products that would be generated by Team A. The end user proxy and Team A jointly reviewed and negotiated changes to them.

In the process of moderating the discussions the Fredrik Team learned how Team A proposed to modify their current work processes and tools to support the needs of this end user. In parallel, the Fredrik Team observed and documented how Team A worked for other users, paying close attention to what tools and references were used and how each discipline position (role) on Team A contributed to the overall end product.

The Fredrik Team documented a draft of the expected end products, the Team A position responsible to produce

these products, and the overall Team A process to produce them. The process documentation included identification of specific tools and reference information. This set of information yielded draft requirements for a Fredrik Team A prototype.

4.1.2. Rapid Design & Build In order to rapidly deploy a usable prototype for Team A, the prototype was limited to readily available web based technologies. The requirements were reviewed against the available technology and a subset of the requirements was selected to implement for the prototype. The prototype was then designed and built in a development environment. The interface between the development web server and the Project Design Center computing facilities was tested and "bugs" were fixed. (See Figure 2 for the PDC/Team A facility and equipment configuration.) A graphical user interface to Fredrik was designed for the prototype (see Figure 3). The prototype "version 1" was then ready for further interaction with Team A and the end user proxy.

4.1.3. User Testing, Prototype Modification, and Operational Delivery Team A conducted a simulated mission concept design session with the end user proxy. The Fredrik Team used the session to familiarize Team A with Fredrik's features and user procedures. The Fredrik Team also observed Team A's work (as described in 4.1.1. above) and additionally noted Team A questions, comments, likes and dislikes about the Fredrik work environment. These notes were analyzed, requirements were updated and "version 2" of the prototype was built and integrated with the PDC computing facilities. This version was used for Team A mission concept design sessions with actual end users (scientists considering mission concepts to propose as SMEX Missions).

Multiple design sessions were conducted. At each design session, Fredrik Team members observed and noted how Fredrik was being used, just as they had in the earlier simulated session. Again, notes were analyzed, requirements were updated and a "final" version of the Fredrik prototype was built.

4.1.4. End Results This effort produced positive results in several areas:

- Team A gained immediate collaborative design process performance improvements. The number of participants in the mission design sessions was decreased by 50%. The number of design sessions was decreased by 66%.
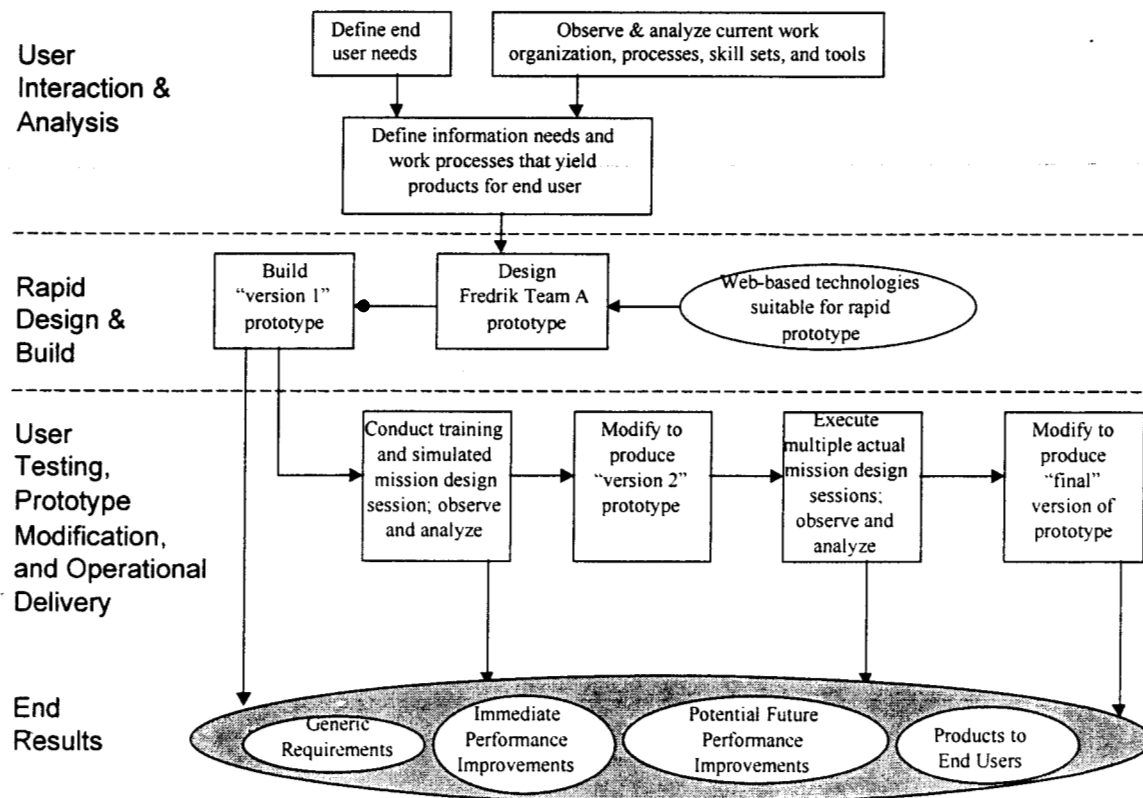

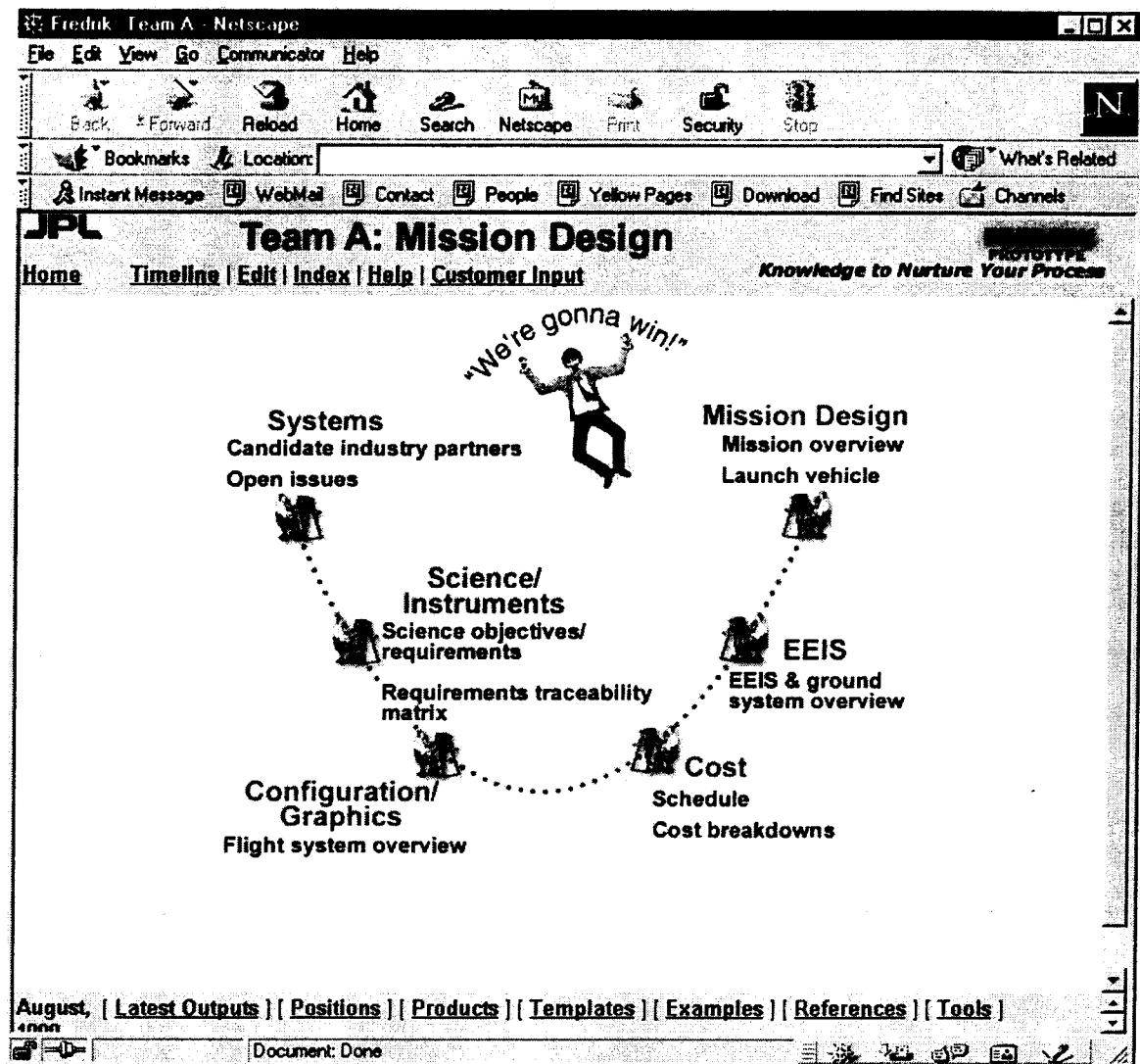**Figure 2. Fredrik Team implementation approach [6]**

Figure 3. Fredrik Team A user interface

- Each end user received a set of seven to ten viewgraph products that described the mission concepts from Team A at the end of a session. This was primarily due to the involvement of the end user proxy in defining the products and process prior to the user sessions.
- Many requirements for performance improvements were identified and documented that could not be implemented in the Fredrik case study, but can be implemented in the future.
- The Fredrik Team conducted a final requirements analysis at the end of the case study and extracted a set of "generic" requirements that can be applied to other processes and products at JPL. [7]

4.2. Team A Conclusion and Further Work

The SMEX Team A design sessions benefited the case study proposal managers, Team A, SESPD and JPL.

The proposal managers received 70-90% of the specified mission design products in one third the design time at one-eighth the cost of the current Team X design approach. This makes Team A an affordable early design resource.

Team A has a tested process and information system that enables them to easily capture, store, retrieve and re-use their intellectual capital.

SESPD has a resource to assure that submitted proposals have received appropriate design resources and are, in fact, do-able at the proposed costs.

JPL has a real time collaborative mission design process to apply its best engineers during early mission formulation. This enables the detection and possible correction of problems very early in the design process. In this case study, one mission proposal was redesigned and a second was withdrawn from the SMEX proposal process because of major design and cost issues discovered by Team A. [8]

4.3. Team A Fredrik Implementation: Status

The current Team A Fredrik process supports the production of a set of ten mission design viewgraphs (user defined products), and defines the Team A roles and responsibilities. The use of templates and examples for each defined product is an important element of the process.

The remaining activities in progress are to:
- finalize the collaborative process for using Fredrik in one design session
- finalize the process for storage, retrieval and reuse of team A-produced products in multiple design and review sessions
- continue the Team A population of the Fredrik tool and reference information database
- finalize the requirements document and selection criteria that can be used to negotiate with an industrial partner to design and implement an information management system that would enable routine, real time, distributed mission design sessions with completed products developed during a design session.

5. Related Work

The Fredrik Team is currently working on the following Fredrik based systems:
- work environment to support development and documentation of science, mission, and project level requirements - early project requirements development prototype;
- process tracking system prototype;
- Proposal process resources database;
- A proposal has been submitted to NASA that extends the Team A work environment to include geographically distributed teams collaborating to produce science mission concepts.

6. Conclusion

The process for designing an IT collaborative system must start with the user requirements. Developing an IT solution is an iterative process and is dependent on continuous management support, frequent interaction with users and measurement of user satisfaction, continuous improvement of the solution based on user feedback, and continuous update of information.

The Fredrik Team approach focuses on working closely with the user to reach a common understanding of and to document their:
- End products and any intermediate products,
- Priorities among products,
- Current work methods,
- Desires to change current work methods,
- Institutional and programmatic constraints,
- Requirements for information access and retention,
- Teaming relationships and team member roles.

The team then reaches an agreement with the user on a limited area of products or work methods that would benefit from the application of immediately available and affordable IT solutions. The team implements the initial incremental solution and collects metrics on the effectiveness of the solution. This provides information to determine requirements for later incremental solutions.

In developing "generic" capabilities, the team looks for similarities among users in the products they produce, their work methods, and the support information required. The focus is on capabilities that are easier to maintain and adapt for specific users. These generic capabilities summarize common needs to build a basis for being a "smart buyer" of commercial IT solutions for JPL.

7. References

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[5] Fredrik Implementation Team, "Team A: Developing Faster and Cheaper Design Solutions: A New Approach to Process System Engineering Tested by the Fredrik Team in FY99", internal presentation, JPL, October 13, 1999.

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